RESEARCH HIGHLIGHT

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PREDICTING TIME TO FOGGING OF INSULATED GLASS UNITS

INTRODUCTION

Predicting the inevitable repair or replacement of insulating glass (IG) (Figure 1) units is a big challenge for building managers. It requires an understanding of potential service life span and the regular collection of field observations of actual performance. IG unit performance and the financial planning necessary for eventual replacement are of prime importance to condominium corporations.

Observations at many buildings with like components allow building managers to correlate visible signs of deterioration with the likely time when repairs or replacement must be undertaken. Prediction of failure times is much more difficult when there are no visible signs of deterioration. "Failure" of insulating glass units is generally considered to occur when clear vision through the unit is obscured by condensation (fogging) within the unit, but there is usually no visual sign when this might occur. This affects the ability of building owners to accumulate funds for repair or replacement at a reasonable rate.

Gerald R. Genge Building Consultants Inc. through CMHC's External Research Program conducted a research project to investigate methods for predicting the time to failure of insulating glass units and to suggest ways of improving the prediction of failure of insulated glass units.

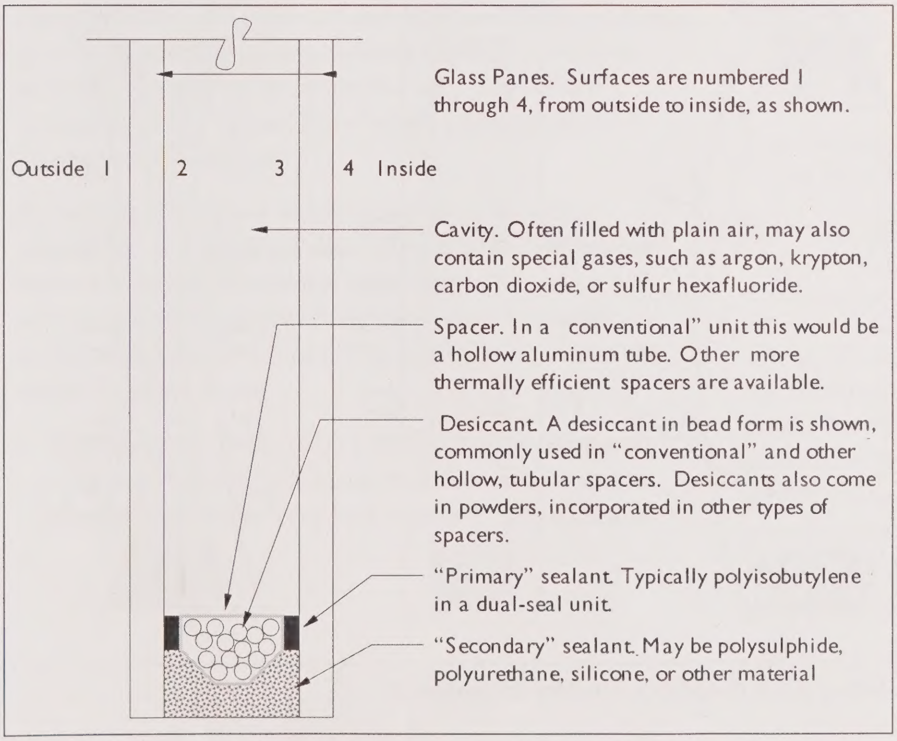

Figure 1: Cross-section through the perimeter of a typical insulating glass unit

OBJECTIVES

The intent of this research was to document common modes of failure of insulating glass units and suggest methods to help building managers predict these failures and develop replacement plans.

The work elements included the following:

- Undertake a literature search to document performance and failure modes of IG units
- Assess existing IG unit failure prediction methods
- Suggest and test new prediction tools
- Recommend next steps

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PERFORMANCE OF INSULATING GLASS UNITS

This portion of the research reviewed and summarized information about why and how insulating glass units fail. The time to fogging is directly related to:

- **Moisture content of the cavity gas fill:** During manufacturing, the desiccant is exposed to the air in the manufacturing facility and adsorbs water vapour from it. Adsorption means water vapour is attracted to and condenses on the surface of the dessicant with no chemical combination of the two. If the latter occurs, then this is defined as absorption. If significant amounts of water vapour are adsorbed, the available moisture adsorption capacity of the desiccant in service is reduced, as is the amount of water vapour required to diffuse into the unit through the perimeter sealants to cause fogging.
- **Permeability and cross-section area of the perimeter sealants:** Permeability of insulating glass unit perimeter sealants varies (Figure 2). Polyisobutylene sealants have the highest resistance compared to polysulphide, polyurethane or silicone sealants. The volume of air trapped within an insulating glass unit changes, forcing the glass panes apart or causing them to bend (Figure 3) which causes the perimeter sealants to be stretched or compressed, affecting the path length and area of the sealants and, thus, their permeance.
- **Type and quantity of desiccant:** The desiccant in the perimeter spacer must adsorb water vapour and any volatile compounds that might be present (from sealants or paints). The greater the amount of desiccant, the longer the life span and vice versa.
- **Service environment:** The difference in water vapour concentration between the cavity gas fill and the environment outside the insulating glass unit to which the perimeter seal is exposed affects service life. The rate of water vapour transmission across the perimeter sealants is greater when the units are exposed to more humid service environments, shortening the time to fogging.

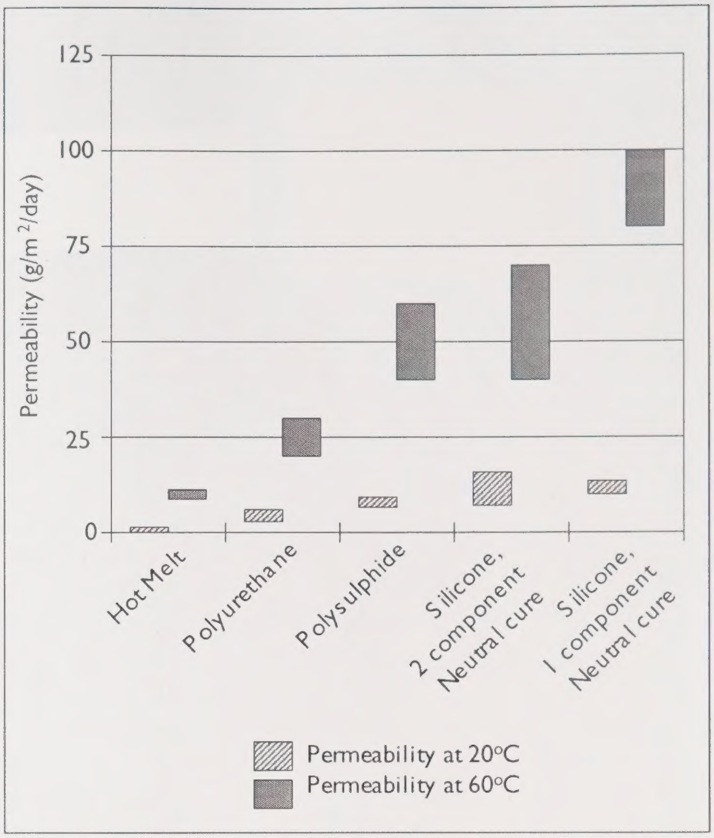

Figure 2: Water vapour transmission rates (permeability) for various insulating glass unit sealants

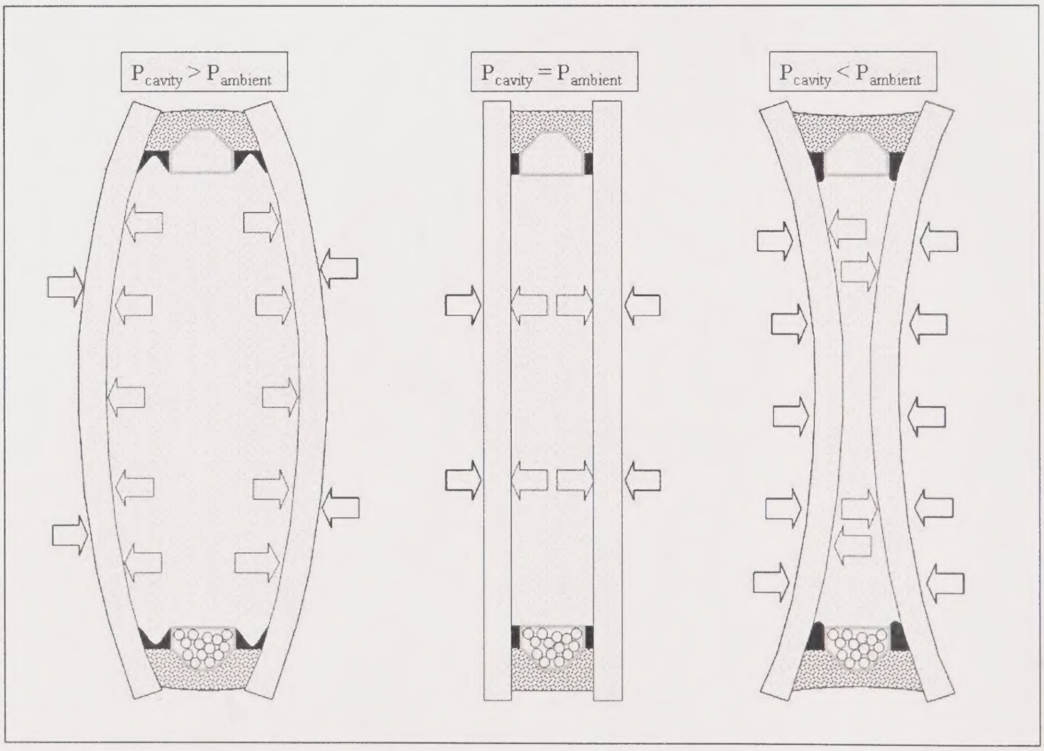

Figure 3: Effect of pane flexibility on sealant configuration

Prolonged contact with liquid water will degrade the perimeter sealants, also shortening the time to fogging (this is considered to be the most common cause for early fogging of units).

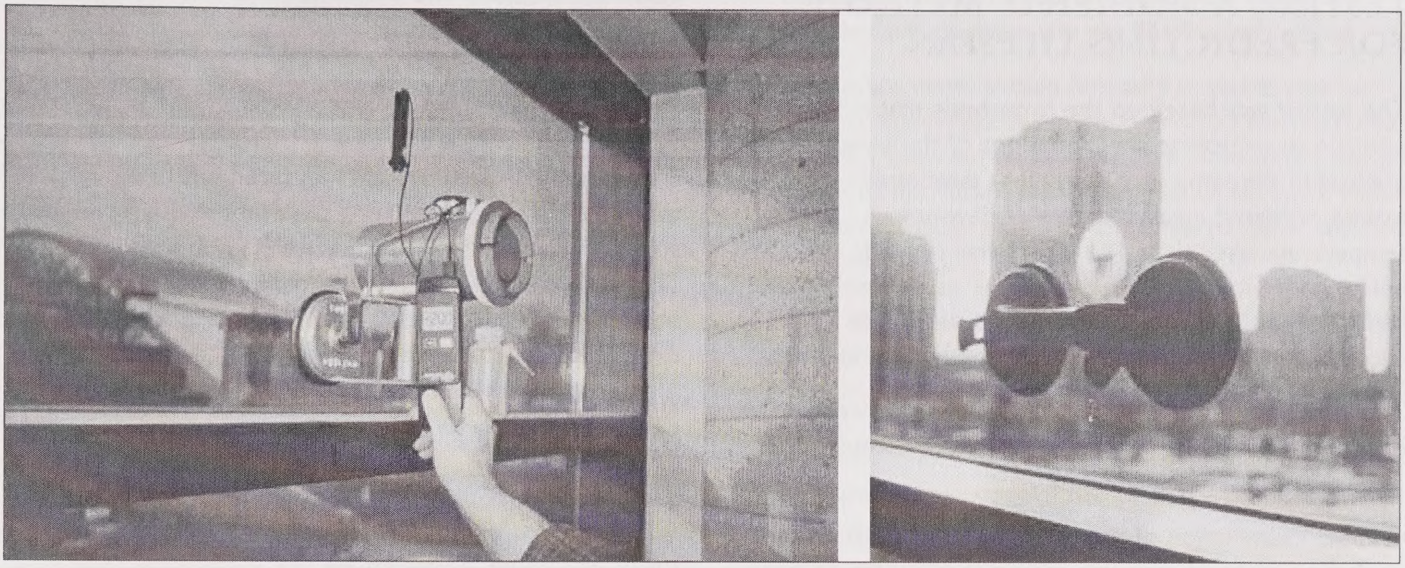

Figure 4: Field dew-point measurement apparatus: (Left) The unit is mounted on an insulating glass unit in contact with the inboard pane of glass. A digital thermometer inserted into the unit measures the temperature of unit in contact with the pane. (Right) The apparatus has been removed (except for the suction cups), revealing a circle of condensation or frost on the cavity-side surface of the pane, directly beneath the chilled contact area of the apparatus.

EXISTING METHOD FOR PREDICTING LIFE SPAN

A method to estimate time to fogging of insulating glass units installed in buildings was proposed in the 1980s (Spetz). It uses an indirect determination of the insulating glass unit cavity dew-point temperature (Figure 4) to estimate the degree of saturation of the desiccant contained in the spacer, from which a likely time to fogging can be inferred.

By relating dew-point measurements to desiccant manufacturer's technical data, it is possible to estimate desiccant moisture content (units with desiccant moisture content approaching saturation are likely to fail within a short time). This approach results in the following predictions:

- Dew-point less than -62°C (-80°F): there is almost no moisture in the IG unit cavity, thus the IG units can be expected to have a "very long expected future clear life"
- Dew-point between -62°C (-80°F) and -18°C (0°F): there is some moisture in the cavity, thus the IG unit can be expected to have a future clear life less than units with a dew-point temperature less than < -62°C (-80°F)
- Dew-point between -18°C (0°F) and 0°C (+32°F): there is "considerable" moisture in the air space, thus the IG units will have a relatively short future life. Estimation of remaining life span requires knowledge of the construction of the units, including the desiccant type and manufacturer;
- Dew-point greater than 0°C (32°F): permanent fogging of glass surfaces within the insulating glass unit (exposed to the cavity) can be expected to develop within two years.

There are two major drawbacks to this method. First, it is necessary to know the desiccant type and manufacturer—possible only if the IG unit manufacturer is still in business and cooperative. Second, only the last prediction comes with a timeframe and it is too short (two years), providing insufficient time for building owners to accumulate the substantial funds needed for replacement in modern high-rise buildings.

TESTING A MODIFIED METHOD FOR PREDICTING LIFESPAN

The testing was based on the hypothesis that it should be possible to overcome the limitations of the existing test method in the same way it was first developed—by making repeated measurements of dew-point temperature over time. The intent was to apply a performance measurement technique using accelerated laboratory testing to determine if the technique could be successfully used to predict when units would fog.

Twelve standard test-size insulated glass units were obtained from an accredited Toronto area manufacturer. The test program consisted of

- Initial examination of the units, including destruction of three units to measure desiccant moisture content.
- Repeated cycles of exposure to elevated temperature and humidity to increase the rate of water vapour transmission into the cavity and thus increasing the cavity moisture content and dew-point temperature.
- Measurement of the dew-point temperature of the units was between exposure cycles.
- Development of mathematical models, based on test measurements, to predict future dew-point temperatures and time to fogging. Subsequent dew-point temperature measurements were compared against predicted values to refine the models and the best model was selected.

The initial goal was to induce fogging through elevated temperature and humidity exposure only. However, to meet schedule and funding limitations, modifications to the test procedure were necessary to accelerate failure. Due to difficulties with mathematically predicting time to fogging of the test units during the test program, the development of the models was delayed until all the test data was available. Several prediction models were attempted using the commonly available spreadsheet program Microsoft Excel with one showing greater promise than the others.

The prediction model uses the "Forecast" function in Excel to work with existing data to predict future data. Principally, this function uses the average and standard deviation of the data for as many measurement periods as there are.

From the research, the following three distinct stages of prediction of time to fogging emerge

Stage 1: Dew-point Temperature Not Measurable – No Prediction Possible

The apparatus used for field measurement of dew-point temperature of the insulating glass unit cavity gas fill uses solidified carbon dioxide ("dry ice") to cool the cavity-side surface of one of the glass panes until condensation occurs. As long as the dew-point temperature of the cavity gas fill is lower than about –73°C, it cannot be measured and therefore, no prediction of time to fogging can be made.

Stage 2: Prediction of the Average Dew-point Temperature

Once dew-point temperatures are measurable, it is possible to begin time to fogging predictions.

It is proposed that prediction of time to fogging should only be calculated when the majority of the units in the sample set have measurable dew-point temperatures. It is reasonable to expect that a more accurate prediction would be made with more data (dew-point measurements) at each measurement period. Further work is required to determine how large of a "majority" is required (such as 51 per cent, 66 per cent, and so on). From this analysis the following conclusions were drawn:

- At least three sets of measured dew-point temperatures are needed to make a prediction of time to fogging.
- The accuracy of prediction will change, and become more accurate, as more sets of dew-point temperatures become available.
- The accuracy of prediction can be increased by careful review of trends of dew-point temperature increase, comparing trends for individual units to the overall, and making repeated predictions without suspect units.

Stage 3: Broadening the Prediction

The same method used to predict future average dew-point temperatures (the "Forecast" function in MS Excel) can also be used to predict future standard deviation of dew-point temperatures from the average, and thus the future variation of dew-point temperatures. This would allow prediction of when units that have dew-points higher than the average may fog.

CONCLUSIONS

The research report reviewed the fundamentals of insulating glass unit performance, the factors affecting life span, current methods for predicting IGU lifespan, and then presented a method for field estimation of lifespan (time to fogging). A laboratory experiment to confirm the method was described, carried out, and the results presented and analyzed. It confirmed that methods of estimating life span of insulating glass units are likely to be unreliable without also obtaining *in-situ* measurement of dew-point temperatures.

Predictions of time to fogging based on the progressive results of the experiment, using embedded functions in the spreadsheet program (MS Excel) were shown to be accurate, when compared against actual laboratory data.

It can therefore reasonably be concluded that a method to predict time to fogging of insulating glass units has been identified and proven accurate.

In summary, the method consists of

- Establishment of a representative sample of the population of insulating glass units in a subject building: A review should be made to determine the likelihood that there may be sub-populations that may have different times to failure, and thus should be tracked separately. Multiple samples should be established accordingly.
- Periodic, indirect, measurements of the dew-point temperature of the cavity gas fill of sample units:

  Measurements should be made in warm weather because dew-point temperatures can be measured earlier than during cold weather. This allows more sets of dew-point measurements to be made which in turn should allow for longer-term predictions of time to fogging.
- After at least three sets of dew-point temperatures have been accumulated, preparation of predictions of time to fogging. Readily available prediction tools, such as the "Forecast" function in MS Excel, can be used. As more measurements are made, predictions should be repeated to improve the accuracy of the estimated time to fogging.

RECOMMENDATIONS

The research findings advance the prediction of time to fogging. Further work is required as follows:

- Further laboratory assessment in a timeframe that does not require intentional breach of the perimeter seal to induce failure.
- *In-situ*, field measurements and predictions of time to fogging. Subject buildings that have insulating glass units with measurable dew-point temperatures should be selected. Such a program could be lengthy, depending on the age of the units monitored and the type and severity of conditions affecting lifespan.

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